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Effect of Display Line Rate and Antialiasing on the Recognition of Aircraft Aspect Angle

Marc D. Winterbottom
The Boeing Company, Mesa, AZ, USA
6030 South Kent, Mesa, AZ 85212

George A. Geri
Link Simulation and Training
6030 South Kent, Mesa, AZ 85212

Byron J. Pierce
Air Force Research Laboratory
6030 South Kent, Mesa, AZ 85212

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Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Readiness Research Division

NOTICES

This technical paper has been reviewed and is approved for publication.

//Signed//

BYRON J. PIERCE
Project Scientist

//Signed//

HERBERT H. BELL
Technical Advisor

//Signed//

DANIEL R. WALKER, Colonel, USAF
Chief, Warfighter Readiness Research Division
Air Force Research Laboratory

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P-23: Effect of Display Line Rate and Antialiasing on the Recognition of Aircraft Aspect Angle

Marc D. Winterbottom
The Boeing Company, Mesa, AZ, USA
Marc.winterbottom@williams.af.mil

George A. Geri
Link Simulation and Training, Mesa, AZ, USA

Byron J. Pierce
Air Force Research Laboratory, Mesa, AZ, USA

Abstract
Increasing display line rate did not improve aspect-angle recognition performance beyond a level predicted by measured display resolution. Image antialiasing improved performance even though it did not increase the measured spatial resolution. Finally, the threshold for aspect-angle recognition was found to be consistent with that obtained for other visual tasks dependent on target spatial detail.

1. Introduction
The performance of visual tasks in a flight simulator can be affected by both display line rate (i.e. addressability) and image filtering, such as antialiasing. Increasing display line rate or implementing antialiasing requires additional computational and graphical resources. Therefore, in order to use a simulator most effectively, these variables should be chosen in accordance with the visual task being performed. Further, the most effective line rate and level of antialiasing may depend on whether the main characteristics of the simulation are terrain properties (e.g., in low level flight), or target-object properties (e.g., in air-to-air combat).

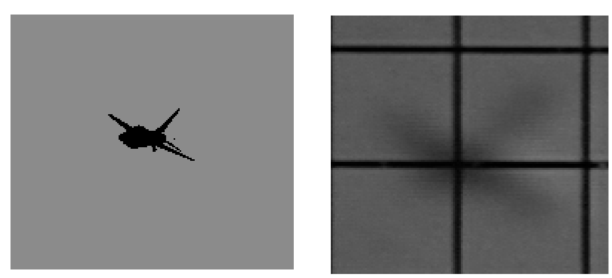
Recognizing a target-object property such as aircraft aspect angle is particularly dependent on spatial detail, and hence, presumably on display line rate. Display line rate, however, is not necessarily a valid measure of display resolution, and so the latter must be assessed in each application. Further, image generator operations such as antialiasing may have no effect on the measured spatial resolution but may nevertheless increase target recognition performance, since the latter may depend also on the temporal properties of the displayed image.

In the present study, we have assessed aspect-angle recognition as a function of both display line rate and whether antialiasing was used. Actual display resolution was also measured in order to determine if line rate, *per se*, affected performance on the aspect-angle task. Finally, the distribution of displayed target size was measured at each simulated range to determine how target size characteristics are related to aspect-angle recognition range.

2. Methods
2.1 Observers
Eleven non-pilots served as observers. Each had normal or corrected to normal vision as determined by the acuity, binocular vision, color vision, and phoria measurement tasks of the Optec Vision Tester (Stereo Optical Co., Inc., Chicago, IL).

2.2 Stimuli and Apparatus
Shown in Figure 1(a) is the F-16 model that was used as a target stimulus. Shown in Figure 1(b) is a digitized video image (right) representing approximately how the model appeared as displayed in the present study. The stimuli were rendered at various distances by either an SGI Onyx2 (Silicon Graphics, Inc., Mountain View, CA) graphics workstation or a MetaVR (MetaVR Inc., Brookline, MA) PC-based image generator (IG) equipped with a NVidia (Santa Clara, CA) GeForce4 videocard. The stimuli were displayed at either 1280×1024 pixels or 1700×1360 pixels on the Onyx2, and either 1280×1024 pixels or 2048×1536 pixels on the MetaVR. Both IGs employed standard antialiasing algorithms. An antialiasing level of 4x was used for all stimuli on the Onyx2, whereas both antialiased (2x) and non-antialiased stimuli were used on the MetaVR.

The target stimuli were black, were presented on a blue (sky) background at the center of the screen, and were rear projected using Barco Model 808 CRTs (Barco, Inc., Kennesaw, GA). The targets were simulated at distances ranging from 3281 to 12000 ft. and appeared at one of two headings (±30 deg) relative to the observer. The targets were moved in a small circle (0.06 deg radius) such that one revolution was completed during the course of the trial (120 deg/sec). This was done so that the target would move across several pixels during the course of the trial. Observers were seated 36 in. from the display.



(a) **(b)**

Figure 1. (a) The F-16 model. (b) A magnified image of the F-16 as it was actually displayed. The gridlines were used for measuring the target aircraft size but were not present during testing.

2.3 Procedure

The first trial in each session was initiated by the observer. In each trial, the observer viewed the F-16 stimulus, and responded, using a mouse, as to whether the aircraft seemed to be pointed to the observer's right or left. The stimuli were presented at the center of the display, and each trial lasted for three sec or until the observer responded. Each session consisted of 240 trials (1 line rate × 6 distances × 2 headings × 20 repetitions). The response data for the two headings were combined. A threshold recognition distance was obtained by fitting a Weibull function to the proportion correct versus distance data and finding the simulated distance corresponding to a criterion level of 81.6% correct. Display spatial resolution was estimated using procedures similar to those suggested by VESA [1]. In addition, the F-16 stimulus was videotaped at each simulated range, and its actual size, as displayed on the rear projection screen, was measured using a calibrated grid as shown in Figure 1(b).

3. Results

Figure 2 shows typical aspect-angle recognition data obtained for one observer. These data were obtained using two line rates and two levels of antialiasing on the MetaVR PC-IG. The threshold recognition level is indicated by the horizontal dashed line, and the corresponding threshold recognition distances are indicated by the vertical lines. Shown in Figure 3(a) are the recognition distances, averaged over all observers, for both line rates tested using the Onyx2 IG. For this IG the difference between mean recognition distances across line rate was not significant ($t < 2.1$, $p > 0.13$, $df = 3$). Analogous data for two line rates and two antialiasing levels tested on the MetaVR IG are shown in Figure 3(b). For the 1280 line rate, recognition distances were 6691 ft and 7328 ft for no-antialiasing and 2x-antialiasing, respectively. For the 2048 line rate, recognition distances were 6785 ft and 7048 ft for no-antialiasing and 2x-antialiasing, respectively. A within subjects repeated measures ANOVA indicated a significant effect of antialiasing (F (1,6) > 18, $p < 0.01$), but no effect of line rate (F (1,6) < 0.4, $p > 0.5$).

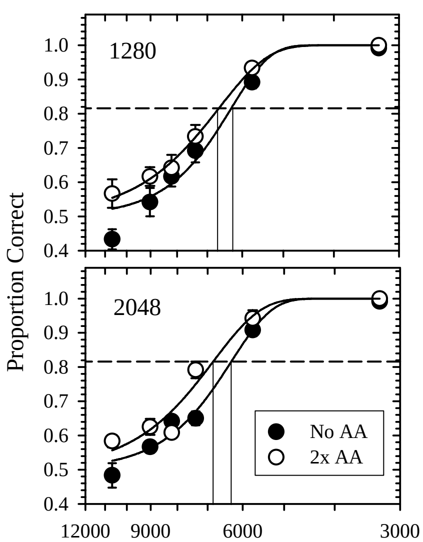


Figure 2. Aspect Angle recognition proportion correct as a function of target range for one observer on the MetaVR IG. Data are shown for two line rates and two levels of antialiasing.

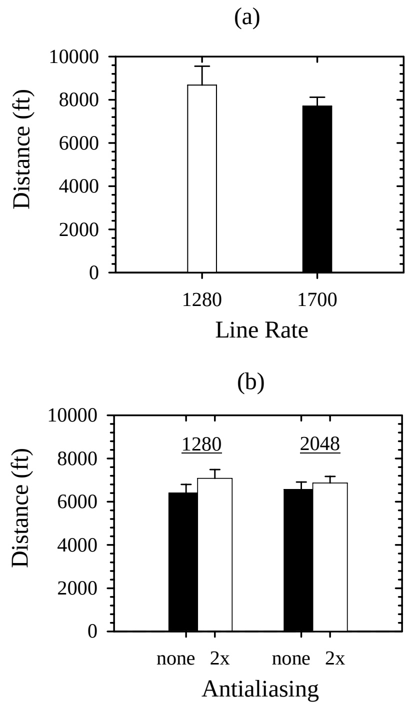


Figure 3. Mean threshold recognition distances for the two line rates tested with 4x antialiasing on the Onyx2 (a), and for the two line rates and two antialiasing levels tested on the MetaVR (b).

Table 1 summarizes the results of the spatial resolution measurements for each display system and line rate tested. The methods used to make these measurements are similar to those described by VESA [1]. Briefly, vertical and horizontal black and white grille patterns are generated by the IG and projected by the display to be measured. A CCD camera is then used to measure the luminance of the grille patterns as the width of the grille lines is varied. A contrast value is calculated from the luminance measurement, and the grille line width corresponding to a contrast of 25% (recommended by VESA) is estimated. The measured display resolution is determined by dividing the nominal line rate by the extrapolated grille line width corresponding to the criterion contrast level. For example, on a 1280 x 1024 display, if a vertical grille line width of 1.8 pixels is required to achieve a 25% contrast between the light and dark lines, the measured resolution would be 1280/1.8 = 711 lines.

The results of the size calibration for two of the simulated ranges generated with the MetaVR PC-IG are shown in Figure 4. The size of the target aircraft was measured by videotaping several three second trials at each of the simulated distances. During videotaping, a transparency with a grid consisting of 5 mm squares was placed over the target aircraft position on the rear projection screen. The size of the target aircraft was then recorded every ten frames on the videotape for each simulated distance, line rate, and antialiasing condition. Approximately 90 size measurements were obtained for each simulated distance. This procedure was repeated for each line rate and each level of

Table 1. Measured resolution compared to the nominal line rate for each IG and level of antialiasing.

SGI Onyx2 (4x antialiasing)	
Line Rate	Resolvable Lines
1280	875
1700	908
MetaVR PCIG (No antialiasing)	
Line Rate	Resolvable Lines
1280	704
2048	741
MetaVR PCIG (2x antialiasing)	
Line Rate	Resolvable Lines
1280	694
2048	718

antialiasing. Figure 4 shows the distribution of target sizes for two of the simulated distances. The vertical dashed line indicates the correct size (i.e., the visual angle appropriate for the simulated distance) while the solid vertical line indicates the measured mean target size.

Figure 5 (black bars) shows the difference between the measured mean target size and the correct size for each condition tested on the MetaVR. The use of antialiasing reduced the difference between mean target size and correct target size. Increasing display line rate also reduced the difference between mean target size and correct target size. The difference between the correct and actual target sizes becomes more pronounced as the simulated distance is increased. The differences between the 90th percentile target size and the correct target size are also shown in Figure 5 (white bars).

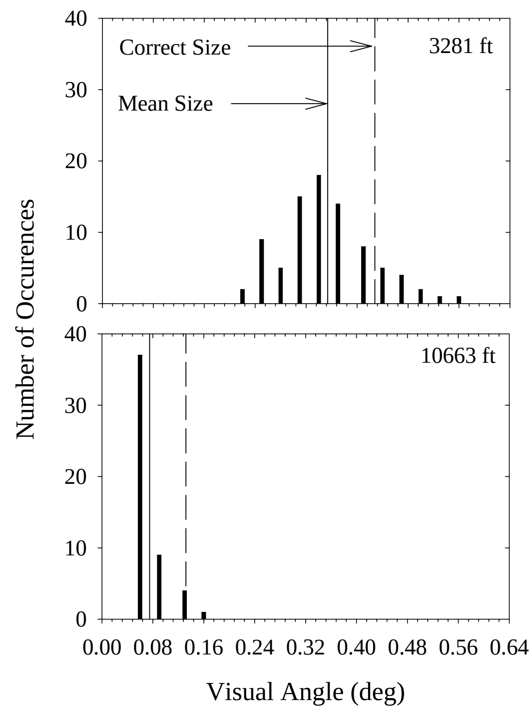


Figure 4. Target size calibration data for two simulated distances at the 1280x1024 line rate with no antialiasing on the MetaVR IG.

4. Discussion

It is generally expected that higher line rates should result in greater spatial detail in a displayed image. It is also known, however, that in many raster-display systems, greater detail is associated with a decrease in image contrast. The data shown in Figure 2 indicate that there is no effect of line rate on aspect-angle recognition distance. Spatial resolution measurements obtained in accordance with a VESA standard [1] are shown in Table 1, for all combinations of IG settings and display line rate used in the present study. For both IGs tested, the number of resolved lines is about equal for each line rate. Spatial resolution therefore correlates better with aspect angle recognition than line rate. It is generally accepted that a distinction must be made between display line rate (addressability) and display resolution [2]. However, it is not known whether line rate *per se* has an effect on tasks, such as aircraft aspect-angle recognition, that are dependent on the spatial detail of target objects. The present data indicate that display resolution is a valid indicator of the suitability of the tested display systems for simulating at least one visual task dependent on spatial detail.

The data of Figure 3(b) indicate that antialiasing improved aspect-angle recognition, even though it did not improve the spatial resolution of the displayed image (see Table 1). However, antialiasing did significantly reduce flickering of the target, particularly at the lower line rate (1280), caused by its movement across adjacent display pixels. Thus, the use of antialiasing may have kept the target visible for a greater percentage of the experimental trial and hence improved recognition performance.

Evidence of the flickering of target aircraft is clearly shown by the size calibration data. In Figure 4, for example, the mean target size for 3281 feet is 17% smaller than the correct size. This is because flickering of the stimulus is associated with a disappearance of the higher detail portions of the aircraft, such as the wings and tail. Antialiasing reduces this flickering because the image is represented in video memory by a larger number of samples. This increases the likelihood that the finer details in the aircraft image will be drawn during image rendering. Based on a description provided by NVidia [5] an illustration is provided in Figure 6. The left side of Figure 6 shows the aircraft model, the equivalent area of pixels on the CRT (squares), and the sample locations (white circles) for both no-antialiasing and 2x-antialiasing. The right side of Figure 6 shows how the model would be rendered based on the sample locations shown in the illustration. With no antialiasing samples that fall on part of the aircraft model will be black. Samples that do not fall on the aircraft will be the background color (light grey). In the case where 2x-antialiasing is used the color at two sample locations will be averaged. One sample point may fall on the aircraft while the other falls on the background. The resulting color of the final pixel will then be the average of those two colors (dark grey). Note that when 2x-antialiasing is turned on there is an increased likelihood that enough information will be presented to determine the aspect of the model. It will also significantly increase the likelihood that small features of the

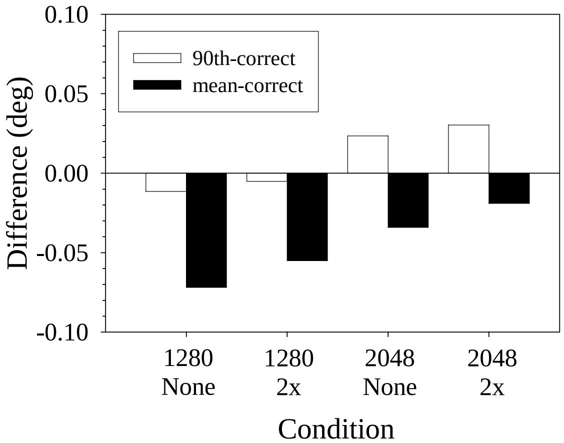


Figure 5. Average difference (across all target distances) between mean target size and correct target size for each line rate and each antialiasing level on the MetaVR PC-IG. Also shown is the difference between 90th percentile target size and correct target size.

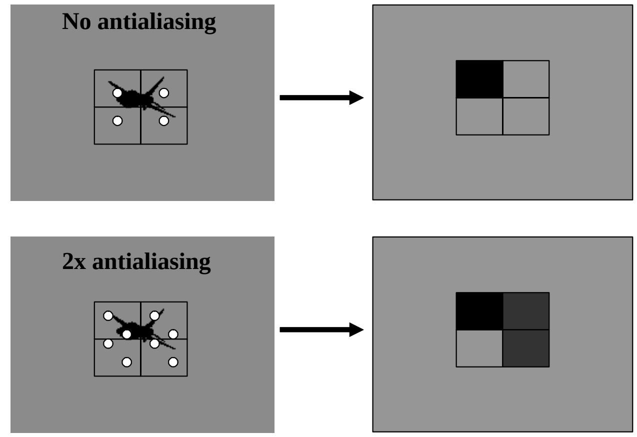


Figure 6. The upper two illustrations show how the IG calculates the color of the rendered pixels when no antialiasing is used. The lower two illustrations show how the IG calculates the color of rendered pixels when 2x antialiasing is used. The white dots in the two left illustrations indicate the sampling locations in video memory relative to the rendered pixels

aircraft model will be rendered. Note that in the top illustration in Figure 6 (no antialiasing), if the aircraft model were moved a small amount to the right and down, two additional rendered pixels would become black. Motion of this kind is what caused the flickering described by observers in this experiment.

Previous research on the display of high spatial frequency targets has found that performance declines with decreasing target size, and that this decline is more pronounced for limited bandwidth displays such as CRTs. For instance, Nasanen, Karlsson, and Ojanpaa [3] found that search times for low contrast characters increased substantially when their size was reduced to about 0.2 degrees. This critical size corresponds to the calculated size of our aircraft targets near our threshold distance of about 7000 feet. The fall-off in performance documented by Nasanen *et al.* [3] also coincides with a fall-off in the modulation transfer function (i.e. the spatial resolution) measured for their CRT display. Finally, the data of Blackwell [4] also show that the contrast required for accurate detection increases substantially for targets smaller than 0.3 degrees, although the contrast required for simple detection was much lower than that required for recognition or identification. These previous findings [3, 4] suggest that our conclusions concerning the relevance of spatial resolution to aspect-angle recognition may also be applicable to other visual tasks dependent on object spatial detail.

5. Acknowledgements

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